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Le Conte's Thrasher (*Toxostoma lecontei)* Occupancy and Distribution: Barry M. Goldwater Range and Yuma Proving Ground in Southwestern Arizona

Scott T. Blackman AZ Game and Fish Dept.
September 2012

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Scott T. Blackman
Shawn F. Lowery
Joel M. Diamond, PhD

Arizona Game and Fish Department
5000 West Carefree Highway
Phoenix, AZ 85086

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RECOMMENDED CITATION

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INTRODUCTION

Le Conte's thrasher (*Toxostoma lecontei*; hereafter LCTH) is an uncommon permanent resident of sparsely vegetated landscapes within the San Joaquin Valley, Kern River basin, Owens Valley, Mojave Desert, and the Lower Colorado River Valley subdivision of the Sonoran Desert biotic community in the southwestern United States (Sheppard 1996, Corman and Wise-Gervais 2005). Nesting occurs from January through May and, rarely, into early June (Sheppard 1970, Sheppard 1996, Corman and Wise-Gervais 2005).

This species is listed as a Bird of Conservation Concern by US Fish and Wildlife Service (USFWS), and as a Wildlife Species of Concern by the Arizona and California Game and Fish Departments (Latta et al. 1999, CalPIF 2006). Within Arizona, the densest concentrations of LCTH occur on the Cabeza Prieta National Wildlife Refuge and the Barry M. Goldwater Range (BMGR) (Corman and Wise-Gervais 2005). Density estimates in California have ranged from 0.2-7.3 pairs/km² (CalPIF 2006). Populations have declined in some areas including California's San Joaquin Valley (CalPIF 2006, CMSHCP 2007) and in Arizona where agriculture and urban development have impacted this thrasher's habitat.

The Department of Defense (DoD) manages large tracts of Sonoran Desert and correspondingly plays a major role in the conservation of this ecoregion (Marshall 2000). The BMGR encompasses 1,733,921 acres (701,718 hectares, 2,709 square miles, or 7,016 square kilometers) and is jointly managed by the U.S. Air Force and U.S. Marine Corps to train military aircrews for air combat missions (BMGR 2007a). The Yuma Proving Ground (YPG) contains approximately 3,450 km² of Sonoran Desert in La Paz and Yuma counties and is currently used for testing training equipment and personnel in the harsh desert environment (Figure 1). As federal land managers, BMGR and YPG personnel comply with the Sikes Act and the Endangered Species Act as part of installation operations. Information on sensitive, threatened and endangered species that potentially occur on BMGR and YPG is needed to make military planning compatible with sensitive species management.

Natural resource monitoring and management at BMGR and YPG is guided by Integrated Natural Resources Management Plans (BMGR 2007a, USYPG 1998) and Inventory and Monitoring Plans (BMGR 2007b, Villarreal et al. 2011). Military activities on BMGR and YPG such as ground-based training and heavy equipment maneuvers involving wheeled and tracked vehicles may negatively impact LCTH. Other military activities that cause moderate to high levels of disturbance to soils and vegetation (e.g., explosive ordnance clearance areas, munitions impact areas) can also threaten LCTH on BMGR and YPG if activities occur within known breeding areas or potential habitat.

The proportion of area occupied (PAO) is a popular alternative to abundance estimation in wildlife monitoring programs because, unlike abundance estimates, PAO metrics incorporate the detection probability of each species (Bailey et al. 2004, MacKenzie and Royle 2005). If the detection probability for a species is not incorporated into occupancy estimates, a naïve count of the area (the number of sites occupied by the species divided by the total number of sites surveyed) will underestimate the actual site occupancy (MacKenzie et al. 2002, MacKenzie et al. 2003, Tyre et al. 2003, MacKenzie and Nichols 2004). PAO estimates are calculated using the likelihood-based approach described by MacKenzie et al. (2002) that accounts for species or individuals present but undetected during surveys.

GOALS AND OBJECTIVES

The goals of this project were to elucidate the PAO of LCTH on BMGR and YPG in southwestern Arizona during the 2011 breeding season. Results from the 2011 LCTH surveys will provide useful information about the distribution of this species on BMGR and YPG and highlight potential habitat attributes that facilitate this species site-specific occupancy. Additionally, we developed a pattern recognition model to predict highly probable LCTH habitat. This will assist BMGR and YPG to manage LCTH for long-term sustainability across these military installations. Our objectives were as follows:

1) Develop a LCTH Prediction of Occurrence Model;
2) Survey for the presence of LCTH within BMGR and YPG and relate site-specific occupancy to habitat attributes; and
3) Determine Proportion of Area Occupied (PAO) for LCTH on BMGR and YPG.

STUDY AREA

Barry M. Goldwater Range East and West

The Barry M. Goldwater Range is co-managed by the U.S. Air Force (USAF) and the U.S. Marine Corps (USMC). The land-management authority for the eastern 1.1 million acres is the 56th Range Management Office (56 RMO) at Luke Air Force Base, Phoenix, AZ. The western portion, more than 600,000 acres, is managed by the Range Management Department at Marine Corps Air Station Yuma in Yuma, AZ. The Range occupies portions of Pima, Maricopa and Yuma counties, from the City of Yuma to several miles East of Gila Bend, Arizona, and totals approximately 7,066 km^2 (Figure 1). The Range is bounded to the south by Mexico and Cabeza Prieta National Wildlife Refuge, to the north by Interstate-8 and a mix of private and public properties, and to the east by the Tohono O'odham Nation and Bureau of Land Management lands.

Elevations at BMGR range from below 200 ft at western portions of the Range to 3,700 ft in the Sand Tank Mountains at the eastern border (BMGR 2007a). Temperatures on BMGR can range from below 0° C (rare) to 49° C, with a range-wide average annual rainfall of approximately 5 inches (BMGR 2007a).

The Lower Colorado River subdivision of the Sonoran Desert is the predominating vegetative community and is characterized by drought-tolerant plant species such as creosote (*Larrea tridentata*), bursage (*Ambrosia* spp.), paloverde (*Parkinsonia* spp.) and cacti (e.g., *Cylindropuntia* spp. and *Carnegiea gigantea*) (Brown 1994, Marshall et al.

2000). The broad, flat and sparsely vegetated desert plains of BMGR are dissected by incised washes characterized by paloverde, ironwood (*Olneya tesota*), smoketree (*Psorothamnus spinosus*), catclaw acacia (*Acacia greggii*), mesquite (*Prosopis* spp.), ocotillo (*Fouquieria splendens*) and other shrubs. The Arizona Upland Subdivision of the Sonoran Desert occurs on elevated hills and mountain slopes of BMGR East, primarily east of State Route 85. Because LCTH does not inhabit the Upland Subdivision, we do not provide a detailed description of this subdivision.

Yuma Proving Ground

The Yuma Proving Ground is managed by the U.S. Army. YPG occupies portions of La Paz and Yuma counties near Yuma, Arizona, and totals approximately 3,450 km^2 (Figure 1). Kofa National Wildlife Refuge and YPG share a 58-mile long boundary (USDI 1996). The elevation at YPG ranges from sea level to 878m. Average temperatures range from 16° C (December) to 30° C (July) (Atmospheric Sciences Laboratory, YPG Central Meteorological Observatory), with average annual rainfall of approximately 8.8 cm.

The prevalent vegetative community on YPG is the Lower Colorado River subdivision of the Sonoran Desert, described above. As at BMGR, the broad, flat plains of YPG are dissected by numerous incised washes. The elevated hills and mountain slopes at YPG are within the Sonoran Desert's Arizona Upland Subdivision, where plants such as beargrass, cacti and agave occur.

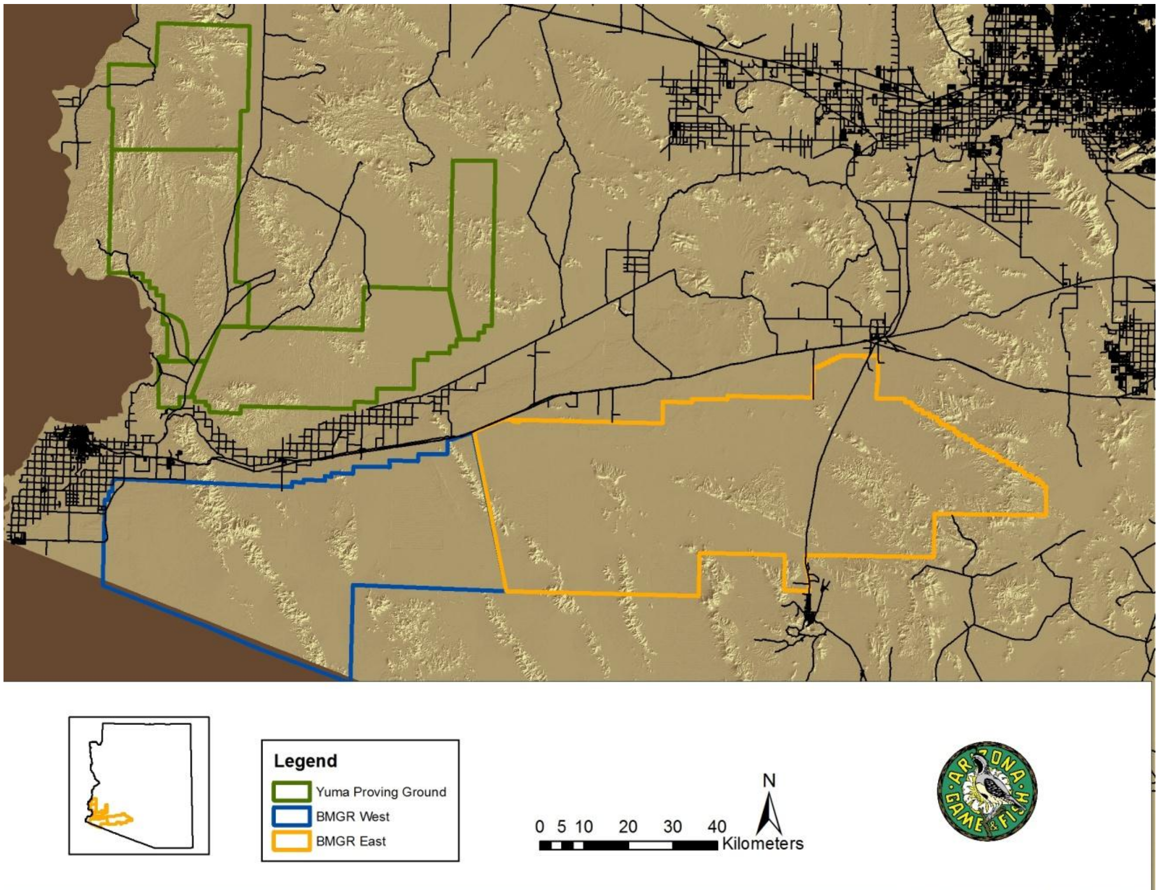

Figure 1. Occupancy surveys for Le Conte's thrasher during 2011 were located at YPG, BMGR East and BMGR West.

METHODS

Prediction of Occurrence (PO) Model

We developed a Geographic Information System (GIS) model to predict LCTH occurrence based on the habitat suitability of the study region and surrounding areas. Model inputs included vegetative cover (SWReGAP), soil series (Natural Resource Conservation Service, NRCS), elevation, and previous LCTH detection locations (Blackman et al. 2010). The GIS model produced a 10-category ranking of potential for LCTH occurrence throughout the modeled area ranging from category one (least suitable LCTH habitat) to ten (most suitable LCTH habitat). We omitted land areas classified in categories 1-5 (least suitable habitat) from further field surveys and analyses because these areas incorporate large amounts of land cover types known to be unsuitable for LCTH. We also omitted areas with limited access and hazard areas including bombing ranges, drop zones and testing (e.g., explosives) ranges.

Using the five best-fitting PO Model categories (categories 6-10), we used ArcMap (Environmental Research Institute, Redlands, California, USA) to randomly generate forty (40) points throughout BMGR East, BMGR West and YPG. These forty points became the center of our survey plots, and were at least 3km apart to ensure independence among LCTH detections. The location of these points was also governed by limited or restricted access areas on the DoD installations. These restricted areas included bombing ranges, drop zones and test ranges as they occur on the three installations. For example, a large portion of YPG on the southern arm (adjoining the Cibola and Kofa arms) contains numerous large restricted areas where explosives are tested. These areas were omitted from survey point distribution due to the completely restricted or extremely limited schedule available for LCTH surveys.

Survey Methodology

Despite inhabiting very sparse landscapes, LCTH can be difficult to detect. These birds are secretive; the colors of their plumage matches the soil surface, and typically forage on the ground beneath shrubs and trees unless enticed to a high perch where the bird may vocalize. Research on this species in the San Joaquin Valley, California, determined that conducting broadcast surveys (i.e., tape-playback calls) is an effective survey technique, especially when compared to walking transects where vocal responses are not elicited (i.e., no broadcasting) (CMHCP 2007).

Survey points were spaced 400 meters apart along transects projecting out from the center of each randomly generated plot (N=30). Two observers began at the center of each randomly generated plot and walked in opposing directions (e.g., North/South or East/West). Broadcast points along each transect were spaced at 400-meter intervals and both surveyors commenced broadcasting once they had walked 400 meters from the original random point (Figure 2). After conducting the first point broadcast, each surveyor then walked 400 meters to the next point. Transects included five points along one transect and five points along a second transect parallel to and 1,000 m away from the original transect (Figure 2). Upon completion of the first survey transect, each surveyor moved 1 km perpendicular to the first transect line to start the second transect line. The second transects were parallel to the first transect and the direction that the surveyor chose to begin the second transect was contingent upon the suitability of the landscape to LCTH occurrence. Double counting was eliminated by skipping broadcast points directly adjacent to points where LCTH were detected if detected birds began to follow the observer.

At each broadcast point, surveyors first spent one minute quietly looking and listening for LCTH. At the conclusion of the first minute, each surveyor broadcast a recording of LCTH vocalizations for 90 seconds in a direction perpendicular to the transect line, followed by a 2-minute period of observation. The observer then broadcast the LCTH vocalizations for another 90 seconds in the direction opposite of the first broadcast direction and perpendicular to the transect line, followed by another 2 minutes of observation. If no LCTH were detected, total survey time at each point was 8 minutes. If a LCTH was detected, the observer stopped the broadcast, spent 15 to 20 minutes observing the LCTH and recording relevant data (see next paragraph), and then moved to the next point. When LCTH were detected and if the bird followed the observer, we reduced the likelihood of double counting (i.e., repeated counts of an individual bird) by skipping adjacent broadcast points.

All surveyors documented the location and tree/shrub species of the perch where each LCTH was first detected. Perch location was recorded using a hand held Garmin (GPS) using the NAD 83 datum projected in UTM Zone 11 (western portion of study area) and 12. Perches were marked with flagging for future measurements. We identified and measured the distance to all birds detected at survey points (Buckland et al. 2001).

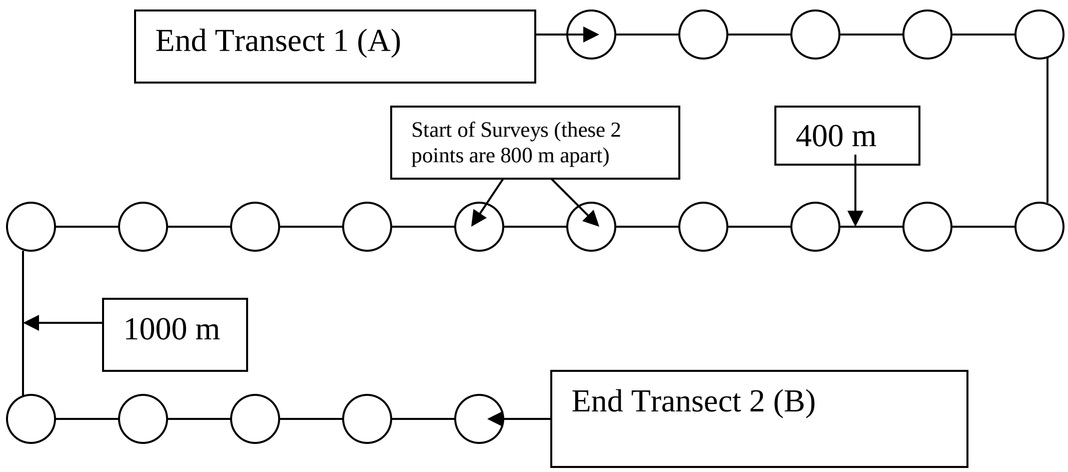

Figure 2. Schematic of parallel transects with call-broadcast survey points conducted by two surveyors walking in opposite directions. The middle 2 points are 800 m apart and are centered about a randomly-generated point. Other points on each transect are 400 m apart. Transects are 1 km apart.

Habitat and Landscape Data Collection

For all LCTH perches and confirmed nests, we recorded the location, described the perch or nest substrate, identified the tree or shrub species and estimated the height of the perch or nest tree. We identified all trees and shrubs within 10 m of all perches, nests, and locations where LCTH were first detected during surveys. At all locations where we detected LCTH, and at alternating broadcast stations, we measured habitat characteristics such as vegetation diversity, proportion of ground cover, percent shrub and tree cover, and the distances to the nearest tree and ephemeral wash. These data were used as covariates within the occupancy modeling framework of LCTH across the 3 DoD installations.

Occupancy Modeling

We used occupancy modeling (MacKenzie et al. 2002) to estimate the occurrence probability and detectability of LCTH throughout the study area and correlate presence/absence with covariates within an information-theoretic context (Burnham and Anderson 2002). Parameters estimated include; (Ψ_i) = the probability that a species is present at site *i*, and p_{it} = the probability that a species is detected at site *i* during visit *t*. Selection of survey locations did not require the presence of LCTH, however, survey locations were randomly generated within boundaries predicted as highly suitable for LCTH occurrence. Randomization and a lack of specific pre-existing knowledge of

LCTH site occupancy eliminated site selection bias (MacKenzie and Royle 2005, Collier et al. 2010).

We developed *a priori* models, formed on the basis of LCTH biology and life history strategies, as a foundation for models used for estimating LCTH detection and occupancy probabilities (MacKenzie et al. 2006). A candidate suite of models contained habitat (e.g., number of trees, distance to nearest wash, distance to nearest tree, sand and gravel cover composition) and landscape attributes (e.g., NRCS soil series classification) associated with LCTH presence (Table 1). We reduced the number of candidate models by evaluating the influence of survey pass on detection probability while holding occupancy constant [$\psi(.)$ p(time)]. We then used the most parsimonious model of detection probability [$\psi(.)$ p(time)] to model the influence of habitat covariates on LCTH occupancy (Kroll et al. 2007, Hansen et al. 2011).

We used the software program PRESENCE version 4.0 (Hines 2010) to model the probability of detection and occupancy with habitat and landscape covariates measured at LCTH detection points and alternating broadcast points across the study areas. LCTH presence/absence data were analyzed at differing spatial scales to generate an occupancy spectrum. This multi-scale method ranged from modeling all individual points together, modeling individual broadcast points consisting of even and odd only analyses (i.e. alternating broadcast points modeled together), broadcast points pooled with respect to Transect A and B, and occupancy modeling at the LCTH plot scale.

Akaike's Information Criterion (AIC) was used to rank the set of considered models in order of goodness of fit (MacKenzie and Bailey 2004) and compare AIC weights and ΔAIC to assess model uncertainty (Burnham and Anderson 2002). We ranked all candidate models with respect to AIC values and interpreted the lowest AIC value as the best model. Models within $<2\Delta AIC$ of the highest ranked model were considered to be best supported by the data and competed with the most parsimonious model.

Overdispersion in the data was assessed by testing overall model fit of the global model by completing 10,000 parametric bootstraps and using the Pearson chi-square statistic to obtain the variance inflation factor ($\hat{c}$) (Burnham and Anderson 2002). Model selection uncertainty was accounted for by computing untransformed parameter and variance estimates within the most supported models (Burnham and Anderson 2002). The AIC weights were summed across covariates represented in the most competitive models ranking within $<2\Delta AIC$ of the highest ranked model to assess the relative importance of the individual covariates.

Table 1. Candidate set of occupancy models applied to Le Conte's thrasher habitat data gathered during repeated surveys on the DoD lands in southwestern Arizona. Estimated parameters include: Ψ_i = the probability that a species is present at site *i*, and p_{it} = the probability that a species is detected at site *i* during visit *t*.

Occupancy Model	Model Description
ψ(.) *p*(.)	Constant occupancy, constant detection
ψ(.) *p*(t)	Constant occupancy, survey pass dependent detection
ψ(Soil) *p*(t)	Soil class dependent occupancy, time dependent detection
ψ(PM) *p*(t)	LCTH Prediction Model dependent occupancy, time dependent detection
ψ(#Tree) *p*(t)	# tree species dependent occupancy, time dependent detection
ψ(DW*) *p*(t)	Distance to wash dependent occupancy, time dependent detection
ψ(DT*) *p*(t)	Distance to nearest tree dependent occupancy, time dependent detection
ψ(Sand) *p*(t)	Percent sand composition dependent occupancy, time dependent detection
ψ(Gravel) *p*(t)	Percent gravel composition dependent occupancy, time dependent detection

*Distance to nearest wash intervals (separate model variables): 0-10m, 10-50m, 50-100m and >100m. Distance to nearest tree intervals (separate model variables): 10-50m, 50-100m and >100m.

RESULTS

Prediction of Occurrence Model

Le Conte's thrasher location data consisting of actual perch locations and points where birds were not detected (Blackman et al. 2010) were modeled with the LCTH Prediction of Occurrence (PO) model for BMGR and YPG. These data are presented in Table 4 with respect to LCTH PO classes 6-10 as these were the best fitting model classes for LCTH occurrence. All but class 10 exhibited increases in the ratio between LCTH perch locations and non-detection locations with respect to increasing predictive power (Table 2). However, the PO Model performed poorly when used as a covariate in occupancy modeling (Table 3).

Table 2. Number of Le Conte's thrasher survey sites and perch locations for five Prediction of Occurrence Model Classes.

Prediction of Occurrence Model Class	Number of Survey Sites and Percentage of Total Sites	Number of LCTH Perches and Percentage of Total Perches	Percentage of Sites with LCTH Perches Within Each PO Class
6	214 (28)	17 (15)	7.9
7	195 (26)	17 (15)	8.7
8	215 (28)	48 (44)	22.3
9	87 (11)	23 (21)	26.4
10	46 (6)	5 (5)	10.9

Call-broadcast Surveys

We conducted surveys for Le Conte's thrashers from January to April 2011. Across the three DoD installations, we detected 183 LCTH at 107 points within 28 plots. Additionally, ten LCTH were observed incidentally while observers walked between survey points or en route to surveys; these 10 LCTH were found at plots where LCTH were detected from established survey points and were not included in occupancy analyses.

Le Conte's thrashers bred at our study area during our surveys. We found three active LCTH nests, and probably detected several male-female pairs. Two LCTH were simultaneously detected from 48 points within 21 plots, potentially consisting of pairs. Observers simultaneously detected three LCTH from five points within five different plots. Because thirteen of the detections consisting of two or more LCTH observations were made after March 1, at a time when we would expect to observe LCTH pairs and/or fledglings, this suggests that breeding had occurred or was in progress at these 13 locations.

Surveys at YPG

Because of restricted access and that LCTH are not likely to occur at vast areas of YPG, we conducted relatively few (n=8, 20% of all surveys) LCTH surveys on YPG. We did not detect LCTH at all three plots (10, 15 and 32) located in the Cibola Arm of YPG. Most of the soil surface within the Cibola Arm is desert pavement, a substrate that LCTH finds unsuitable (Blackman et al. 2010). Likewise, we did not detect LCTH at two of the plots (22 and 22-2) north of the Tank Mountains on the Kofa Arm where desert pavement is prevalent. However, we detected LCTH at all three plots (14, 20 and 43) south of the Palomas Mountains on the Kofa Arm where the soil surface was predominantly softer sands with relatively less gravel (Appendix 1).

Table 3. Mixed occupancy models for covariates supported by the Le Conte's thrasher occupancy data as compared to the global model, presented with Akaike Information Criteria (AIC) values, ΔAIC, AIC weight, and likelihood.

Model	*AIC*	Δ*AIC*	*AIC w*	*K*	*-2Log*
G+(#T)+DW(0-10m) +DT(10-50m)	697.42	0.0	0.3104	6	685.42
G+(#T)+DW(0-10m) +DT(10-50m)+S	697.95	0.53	0.2381	7	683.95
G+(#T)+DW(0-10m) +DT(10-50m) +DW(10-50m)	699.04	1.62	0.1381	7	685.04
G+(#T)+DW(0-10m) +DT(10-50m) +T>100m	699.16	1.74	0.1300	7	685.16
G+(#T)+DW(0-10m) +DT(10-50m)+S + DW(10-50m)	699.70	2.28	0.0993	8	683.70
G+(#T)+DW(0-10m) +DT(10-50m)+S +DW(10-50m) +T>100m	701.34	3.92	0.0437	9	683.34
G+T(10-50m) +DW(0-10m)	702.95	5.53	0.0195	5	692.95
G+T(10-50m)+#T	703.68	6.26	0.0136	5	693.68
Global	705.90	8.48	0.0045	13	679.90
G+T(10-50m)	708.14	10.72	0.0015	4	700.14
G+#T+DW(0-10m)	709.23	11.81	0.0008	5	699.23
Gravel (G)	712.03	14.61	0.0002	3	706.03
G+#T	712.76	15.34	0.0001	4	704.76
G+#T+S	712.77	15.35	0.0001	5	702.77
Global-G	715.59	18.17	>0.0001	12	691.59
(#T)+DW(0-10m) +DT(10-50m)	720.25	22.83	>0.0001	5	710.25
P(T)	739.71	42.29	>0.0001	4	731.71
T(10-50m)	744.09	46.67	>0.0001	3	738.09

Surveys at BMGR East

Fourteen plots were randomly distributed across BMGR East (Figure 3). Most surveys conducted on BMGR East were located in the San Cristobal Valley, east of the Mohawk Mountains. Consistent with the results of the LCTH surveys we conducted at the San Cristobal Valley in 2009 (Blackman et al. 2010), during this study we detected LCTH at 53 locations at ten (71%) plots (Appendix 1). We could not access a plot south of Sentinel and a plot east of SR 85.

Surveys at BMGR West

Our model predicted that much of BMGR West would be suitable LCTH habitat. As a result, a large proportion (18 of 40, 45%) of our survey plots occurred within BMGR West even though BMGR West makes up a smaller proportion of our total study area. Of the eighteen plots at BMGR West, observers detected LCTH at 64 locations within 15 of the 18 survey plots (Appendix 1). LCTH were not detected at plots 18, 23, and 31 (Figure 3).

Perch Locations

The number of trees within 10 m of LCTH perch locations ranged from 0 (n=56), 1 (n=36), 2 (n=12) and 3 (n=3). If no trees were observed within 10m of LCTH perch locations (n=56), we recorded the distance to the closest tree as follows: 10-50m (n=23), 50-100m (n=9), and >100m (n=14). The distances from LCTH perch locations to the nearest wash (of any size) were 0-10m (n=56), 10-50m (n=28), 50-100 (n=10) and >100m (n=13).

Nest Locations

We found three active nests. We found one tree within 10 m of two nest locations. No trees were within 10 m of the third nest; this nest was within a cholla cactus. If no trees were observed within 10 m of LCTH nests, we used the following distances to the nearest tree: 10-50 m (n=1), 50-100 m (n=0), and >100 m (n=0). The desert wash (of any size) nearest to the three LCTH nests were 0-10 m (n=2) and >100 m (n=1) away. Nests were constructed in trees (a paloverde and a mesquite) and shrubs (a cholla cactus). Other species available for LCTH nest placement included blue paloverde, ironwood, and crucifixion thorn. We had insufficient data to determine which plants LCTH favor for nesting.

Occupancy Estimation

The estimated proportion of area occupied (PAO) by LCTH across the three DoD installations was 0.45 (SE ±0.06) and the naïve abundance estimate was 0.14. The probability of LCTH detection across all survey points was 0.11 (SE ±0.02). Occupancy modeling with only the odd survey points along transects produced an occupancy probability of 0.60 (SE ±0.23) and a probability of detection of 0.09 (SE ±0.04). Occupancy model results using only the even survey points along transects producing an occupancy probability of 0.35 (SE ±0.11) and a probability of detection of 0.14 (SE ±0.05). Pooling all points along transect A produced an occupancy probability of 0.88 (SE ±0.40) and a detection probability of 0.07 (SE ±0.03). Occupancy models for all Transect B points produced an occupancy probability of 0.28 (SE ±0.08) and a detection probability of 0.17 (SE ±0.06). Modeling at the plot scale produced an occupancy probability of 0.76 (SE ±0.08) and a model-averaged detection probability of 0.64 (SE ±0.09).

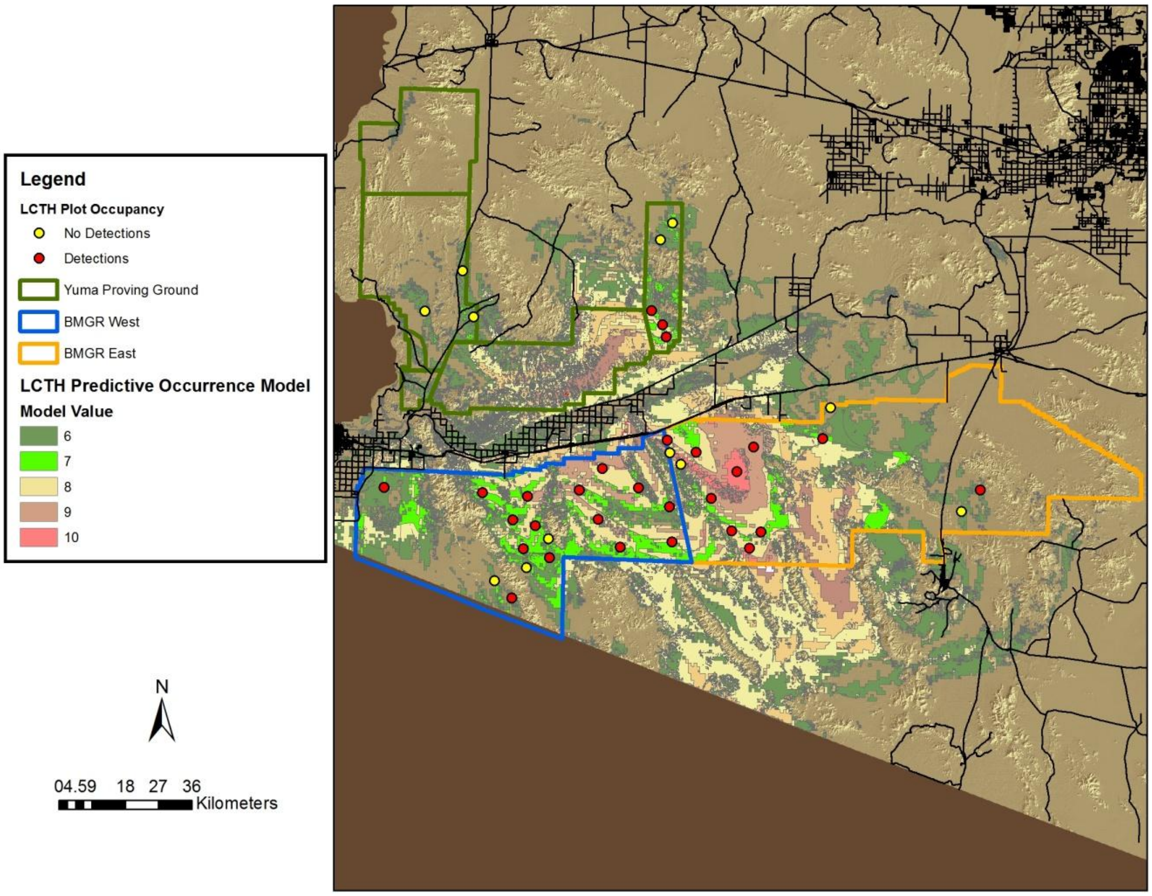

Figure 3. Plots where Le Conte's thrashers were and were not detected during surveys at YPG, BMGR East, and BMGR West during 2011.

Overdispersion was evident in the global occupancy model ($\sqrt{\hat{c}} = 2.45$) and the standard errors were adjusted using the variance inflation factor. The highest ranking occupancy model contained four covariates: percent gravel composition, total number of trees within the plot, distance to nearest tree of 10-50 m when trees were not present within the plot and a nearest wash distance of 0-10 m (Table 3). Three other models were within <2 ΔAIC of the most parsimonious model. These models contained the four covariates used in the highest ranking model and, in order of decreasing importance, percent sand composition, nearest wash distance of 10-50 m and nearest tree distance of >100 m. Percent gravel composition contained the highest parameter importance, followed by, in decreasing order of importance, nearest tree distance of 10-50m, nearest wash distance of 0-10m, and number of trees on plot (Table 3).

Model selection uncertainty of the most supported models was fairly high (AICw <0.30). Therefore, we examined untransformed parameter estimates from covariates included in the best supported model (Table 4). Untransformed standard errors were high for all of the parameters included in the most parsimonious model due to the high degree of model selection uncertainty (Burnham and Anderson 2002). Additionally, we summed the AICw for covariates represented in the most competitive models ranking within $<2\Delta AIC$ of the highest ranked model.

Soil Context

We assigned NRCS soil map units and/or associations to all locations where we detected LCTH, and to a set of randomly selected points where LCTH were not detected. Because the NRCS soil map unit GIS layer was not available for YPG, we could not make a direct comparison between YPG and BMGR based on soil map units. As a result, NRCS soil associations were used as a surrogate.

The majority of the points (including LCTH detections and the random non-detection points) were within the Rositas Soil Complex (Rositas sand and Rositas-Ligurta map units, Table 5). Other prevalent soil map units without LCTH detections were the Cheroni-Cooledge-Hyder, Gunsight-Hyder-Riverwash, Lomitas-Rock outcrop-Quilotosa, and Mohall-Pahaka-Valencia (Table 5). The majority of the detection and non-detection locations for the Soil Association level of detail were contained within the Tremant-Coolidge-Mohall classification (Table 6). Soil associations without LCTH detections were the Gunsight-Rillito-Pinal, Laveen-Rillito, and Lithic camborthids-Rock Outcrop-Lithic Haplagrids (Table 6).

Avian Community

During LCTH surveys we detected the following 63 species: American kestrel, Anna's hummingbird, ash-throated flycatcher, bank swallow, Bendire's thrasher, black-chinned hummingbird, black-tailed gnatcatcher, black-throated sparrow, blue-gray gnatcatcher, Bullock's oriole, burrowing owl, cactus wren, Costa's hummingbird, common raven, crissal thrasher, curve-billed thrasher, Eurasian collared-dove, European starling, Gambel's quail, gila woodpecker, gilded flicker, golden eagle, great horned owl, greater roadrunner, Harris's hawk, hooded oriole, horned lark, house finch, killdeer, ladder-backed woodpecker, loggerhead shrike, lesser goldfinch, mourning dove, northern flicker, northern harrier, northern mockingbird, northern rough-winged swallow, orange-crowned warbler, osprey, phainopepla, red-tailed hawk, rock wren, rufous hummingbird, sage sparrow, sage thrasher, Say's phoebe, Scott's oriole, short-eared owl, Townsend's warbler, turkey vulture, verdin, vermilion flycatcher, vesper sparrow, western kingbird, western meadowlark, western tanager, white-crowned sparrow, white-throated swift, white-winged dove, Wilson's warbler, yellow-rumped warbler, and yellow warbler.

Table 4. Mixed model logistic regression for covariates supported by the Le Conte's thrasher occupancy data as compared to the global model, presented with Akaike Information Criteria (AIC) values, ΔAIC, AIC weight, and likelihood.

Model	*AIC*	Δ*AIC*	*AIC w*	*K*	*-2Log*
DW 0-10m	754.14	56.72	>0.0001	3	748.14
#Trees	755.03	57.61	>0.0001	3	749.03
Sand	755.19	57.77	>0.0001	3	749.19
DW 10-50m	755.37	57.95	>0.0001	3	749.37
T>100	760.23	62.81	>0.0001	3	754.23
Soil Series (Torriothents)	761.51	64.09	>0.0001	3	755.51

Table 5. Untransformed parameter estimates and standard errors (adjusted using variance inflation factor of 2.45) in most supported Le Conte's thrasher occupancy model.

Model	*Parameter Est.*	*SE*
Gravel	-1.2553	2.8803
# trees	-1.894	3.4825
DW 0-10m	2.2871	4.1015
DT 10-50m	-4.175	5.0737

Table 6. Le Conte's thrasher perch location and non-detection locations within respective soil map units.

Map Unit Name	LCTH Perch Locations (count and percent)		Non-detection Locations (count and percent)	
Rositas-Ligurta	36	35.6	177	27.0
Rositas sand	34	33.7	221	33.7
Torriorthents-Torrifluvents	8	7.9	74	11.3
Gunsight-Pinamt-Carrizo	6	5.9	34	5.2
Laposa-Schenco-Rock outcrop	6	5.9	71	10.8
Wellton loamy sand	4	4.0	13	2.0
Harqua-Tremant	3	3.0	22	3.4
Wellton-Dateland-Rositas	2	2.0	8	1.2
Antho Sandy Loam	1	1.0	1	0.2
Laposa-Rock outcrop	1	1.0	20	3.1
Cheroni-Cooledge-Hyder	0	0.0	3	0.5
Gunsight-Hyder-Riverwash	0	0.0	3	0.5
Lomitas-Rock outcrop-Quilotosa	0	0.0	7	1.1
Mohall-Pahaka-Valencia	0	0.0	1	0.2

Table 7. Le Conte's thrasher perch location and non-detection locations in NRCS soil associations.

Map Unit Name	LCTH Perch Locations		Non-detection Locations	
Tremant-Coolidge-Mohall	90	80.4	441	60.8
Harqua-Perryville-Gunsight	11	9.8	149	20.6
Torrifluvents	9	8.0	48	6.6
Supersition-Rositas	2	1.8	14	1.9
Gunsight-Rillito-Pinal	0	0.0	38	5.2
Laveen-Rillito	0	0.0	8	1.1
Lithic camborthids-Rock Outcrop-Lithic Haplagrids	0	0.0	27	3.7

DISCUSSION

LCTH Prediction of Occurrence (PO) Model classes (6-10) were selected for analyses because these categories predicted the areas with the highest probability of LCTH occurrence throughout the modeled area. Categories 1-5 incorporated large areas unsuitable for LCTH occurrence, and were omitted from any analyses. The PO model performed poorly when used as a covariate in occupancy modeling, ranking well below the global model. Interestingly, most of the LCTH detections resided in category 8 of the LCTH PO model despite category 9 and 10 containing a higher LCTH predictive power. However, category 9 contained the highest proportion of detection/nondetection when compared to the other four classes. Category 10 had a low detection/nondetection proportion; however, this class also contained the lowest sample size. Despite the poor performance of the PO model as a covariate in the occupancy modeling framework, the model still functioned at the operational level for LCTH occurrence within predictive classes 6-9. Class 10 may still hold promise for predicting LCTH occurrence but is difficult to validate because of its rarity in comparison to the other PO classes. Categories 6-10 of the PO Model can be overlaid into a geo-referenced map in Arcview providing land managers accurate maps of areas where LCTH are most likely to occur within their jurisdiction. This could be a powerful conservation tool for land managers, helping to identify priority LCTH habitat that may exist in proposed footprints for military activities or development (e.g., alternative energy construction areas).

Surveys conducted in 2009, primarily at the San Cristobal Valley within BMGR East, verified the purported high abundance of LCTH in this portion of the state (Blackman et al. 2010). During those surveys, the distribution of LCTH detections were not uniform across the sampled area and were most concentrated within the center of the valleys where softer sand predominated and trees were sparse (compared to the mountain foothills). Correspondingly, in that study, LCTH were not detected at all survey locations where this species occurrence was predicted by the PO model and where the landscape appeared suitable.

LCTH surveys in 2011 encompassed a larger area throughout DoD lands in southwestern Arizona and consisted of 3 survey passes within an occupancy modeling framework. As expected, these occupancy surveys documented more LCTH locations than surveys conducted in 2009 exclusively in the San Cristobal Valley with only one survey pass. Among the three DoD installations we surveyed, most LCTH were detected at BMGR (East and West), in part because most survey plots were located at BMGR. Within BMGR, LCTH were not detected at plots close to mountain foothills (i.e., bajadas). Likewise, of the three areas we surveyed at YPG, LCTH were detected only in the Kofa arm south of the Palomas Mountains where substrates are softer than at other portions of YPG. Throughout the study area, areas with a gravelly or desert pavement surface lacked LCTH.

No single point within the 28 plots where LCTH were detected was occupied by LCTH during all three survey passes. This demonstrates the general difficulty in detecting LCTH, particularly late during the breeding season. Thirty-six points had LCTH detections only on the second of three passes (February-March). LCTH were not detected until the third survey pass at sixteen points (April-May). These detection results with respect to survey pass explain the low LCTH detection probability and highlight the significance of its incorporation into population estimation. Additionally, PAO estimates were higher than naïve occupancy estimates and emphasize that occupancy estimates will be negatively biased when detection probabilities are not incorporated.

LCTH territories have been reported to be ovate in shape, consisting of 400-450m long and 200-300m wide (Sheppard 1996). Because survey plots were larger than LCTH home ranges, plot-scale occupancy models inflated LCTH occupancy and detection probabilities. Although modeling at the LCTH plot scale produces the highest occupancy and detection probabilities, this model reduces the amount of data available for LCTH distribution and can only incorporate landscape-scale covariates. These results demonstrate how occupancy and detection probabilities can vary depending upon the scale of the analysis. Modeling at the alternating point (odd and even analysis) scale effectively increased the point-scale radius to 400 m, as compared to a 200 m radius comprising the overall broadcast point survey design. Thus, increasing the sampling distance to 800 m would more accurately portray LCTH home range and ensure individual point independence, but would sacrifice individual detection locations and potentially confound raw distribution data. The disparity between occupancy probabilities of even and odd survey points, and between transect A and transect B, indicates that relying on either data set independently would omit individual location data important for mapping LCTH distribution and potentially underestimate occupancy probabilities. Consequently, we recommend that future survey efforts maintain the current LCTH survey protocol and analyze presence/absence data at the plot scale.

Habitat data collected during LCTH surveys in the San Cristobal Valley during the 2009 study revealed that two sand cover categories (packed sand and soft sand) represented the most cover across all LCTH use plots (Blackman et al. 2010). "Packed" and "soft" sand categories both represented substrates conducive to LCTH ground gleaning and digging. Additionally, all 8 plots where LCTH were not detected during the 2009 study were dominated by either hard packed sand or gravel (Blackman et al. 2010). Similar conclusions can be made about LCTH survey results from this study. LCTH were unlikely to be detected at plots near mountains where the soil surface has a relatively high amount of gravel and tree densities are higher than in the lowlands away from the mountains. We anticipated that gravel composition would have a negative influence on PAO (i.e., increases in gravel percent composition were inversely proportional to LCTH occurrence). Gravel composition was the highest ranked individual covariate model and contained a parameter estimate indicating a negative relationship (Tables 3 and 4). LCTH appears to avoid areas where the proportion of gravel at the soil surface is above a certain threshold.

Although the radii sampled around LCTH detection locations were much smaller than LCTH home ranges, the data collected allows for inferences to be made at a larger scale. During the LCTH microhabitat study conducted in the San Cristobal Valley (Blackman at el. 2010), we did not collect some measurements (e.g., distance to nearest tree and wash) that were collected in this study. Numbers of trees within plots, nearest tree distance 10-50 m, and nearest wash distance 0-10 m were all component variables of the most parsimonious LCTH occupancy model. The number of trees covariate produced a parameter estimate indicating a negative relationship, as did nearest tree distance 10-50 m (Table 4). These results could be explained by the general paucity of trees throughout LCTH habitat and all "nearest distance to tree" data was collected for points where no trees were found within the plot. Trees or arborescent structures (e.g., large shrubs) are important for LCTH nesting and that our model suggests a negative relationship between trees and LCTH occurrence is surprising. However, our results could be a function of scale in that LCTH select for trees at the scale of their home range and trees are usually very sparse throughout LCTH habitat in general. Thus, LCTH apparently select areas with low tree density, but not completely devoid of trees.

Several tree species are important to LCTH nesting, including crucifixion thorn and mesquite hummocks (mesquite hummocks act as tree islands within a sparsely vegetated landscape). Only three nests were documented in 2011. Finding LCTH nests is time consuming and was not within the scope of this project. Each nest was in a different plant species. Other studies have documented nesting in large shrubs and even abandoned buildings and vehicles (Sheppard 1970). LCTH nest-site selection may be more driven by vegetation structure than plant taxonomy or diversity.

LCTH detections did not appear to correlate with NRCS soil map units or associations. Correspondingly, all modeled soil types ranked low compared to other covariates in occupancy modeling. However, LCTH could select habitat that is fundamentally described by soil data, but patterns may not have been observable at the scale of this study. Additionally, many soil map units and associations superficially contain very similar characteristics (e.g., soil substrate and vegetation composition) within LCTH habitat. Thus, soil attributes may be too fine a scale for modeling relationships regarding LCTH occurrence. However, our data does reveal soil map units and associations that definitively contain LCTH detections (Tables 5 and 6); a variable that could be useful in its own right.

Occupancy models are useful tools, especially if relationships between habitat attributes and response variables can be discovered (Kroll et al. 2007, Mackenzie 2006). This study presented occupancy models in the context of habitat variables and how they pertain to LCTH occupancy and detection probabilities. However, several other variables (ultimate factors) influence LCTH distribution including: food availability, inter and intra-specific resource competition, depredation, and inclement weather (e.g., infrequent storms and consecutive hard freezes). Habitat variables (proximate factors) may often act as a surrogate for other factors, such as food availability, that affect bird distribution. However, it is difficult to test the relationship between proximate and ultimate factors and this study modeled only the effects of habitat covariates. Furthermore, it is not possible to test the influence of urbanization, technology development (e.g., solar and wind energy projects) and agriculture footprints within the scope of this study as the vast majority of the study areas were either undeveloped or within restricted access sites.

Our results indicate that LCTH have an inherently low detection probability and demonstrate that we were able to examine the influence of site-specific covariates on PAO and detection probabilities under the occupancy modeling framework (MacKenzie et al. 2002). LCTH occupancy and detection probabilities changed with the scale at which the LCTH occupancy data were analyzed. For example, occupancy and detection probabilities differed markedly between odd and even broadcast points (when pooled respectively) and between transect A and transect B. In this study, occupancy modeling at the scale of the survey plot was most appropriate. We recommend that future modeling efforts be conducted at the plot scale. However, as it is important to document as many LCTH detection locations as is feasible, we also recommend that the same survey protocol that was used in 2011 be implemented in 2012 when the second phase of this study occurs. Additionally, we recommend that 2012 survey efforts generate a new set of random plots to be surveyed from those surveyed in 2011. We also recommend that all plots be surveyed four times, even if this requires less overall survey plots be conducted. In 2012, we will continue to monitor LCTH with presence/absence data at survey plots randomly distributed within BMGR and YPG. We will also continue to gather the same habitat data as in 2011 but will additionally collect information pertaining to additional landscape variables: plot distances to mountain foothills and major valley centers, and numbers of proximal washes and trees.

The Le Conte's thrasher Prediction of Occurrence Model will be updated with 2012 survey location data as it becomes available. This model will also be refined with landscape-scale geospatial data obtained by fine-scale imagery such as: distance to mountains and center of the valley; distance to desert pavement; shrub cover at the plot scale and tree associations at the plot scale. Refining the model will allow land managers to predict potential LCTH habitat with greater accuracy and overlay other layers such as military training areas, bombing ranges and areas slated for development footprints (such as wind and solar array locations). This will allow land managers to print large maps containing these overlays and disseminate to the appropriate agents on the ground.

This is the first large-scale study to model the occupancy and detection probabilities of LCTH and provides a benchmark against which future research can be compared. Long-term research is critical for separating natural from anthropocentric fluctuations in wildlife populations and occupancy modeling can provide a reliable alternative to more costly and labor intensive methods for estimating abundance. Despite repeated visits to the same survey locations, occupancy modeling is not in itself an exclusive monitoring technique for determining whether the LCTH population is self-sustaining. Attaching radio-transmitters and tracking LCTH would be useful to elucidate individual movement data such as home range and breeding territory sizes and territory shifts. To determine a population's self-sustainability, it is necessary to gather productivity and survival data through time; however, these types of data are costly to acquire (Henneman and Andersen 2009). High occupancy rates through time at repeated survey locations can indicate a relatively healthy population within areas spared from high anthropogenic impacts.

MANAGEMENT AND RESEARCH PRIORITIES

The US Census Bureau projected that Arizona would add 5.6 million people by 2030, making it the 10th most populated state in the country and ranking in the top five fastest-growing states. Within BMGR and YPG are large expanses of relatively undisturbed Sonoran Desert, mostly of the Lower Colorado River Subdivision. The importance of these un-fragmented areas to LCTH and many other lowland desert species will continue to increase as the landscape surrounding these DoD installations is rapidly developed for agriculture, industries such as alternative energy (solar), and urban expansion.

The DoD installations of southern Arizona, along with the US Fish and Wildlife Service, AZ Game and Fish Department, Bureau of Land Management, National Park Service, Bat Conservation International and Sonoran Joint Venture, are partners in the Sonoran Desert Conservation Partnership Team. In 2007 this team produced DoD Legacy Species-at-Risk documents that, based on the information available at the time, synthesized the ecology and management recommendations for the species of concern shared by the three DoD ranges of southwestern Arizona. Le Conte's thrasher is the only bird among these shared Species-at-Risk. This study addressed the following recommended management and research priorities for LCTH made by the Department of Defense Species-at-Risk project

- Collect data on LCTH distribution in order to evaluate this species' distribution in relation to military training activities and potential threats. This study collected the first season of LCTH occupancy data used to predict occurrence patterns (incorporating a detection probability) and also facilitated setting a benchmark for comparison with future surveys.

- Evaluate effects of habitat conditions and land use on LCTH populations to develop better understanding of their distribution and support development of appropriate management actions. An objective of this study was to describe essential habitat components for LCTH; areas containing softer substrate and containing minimal or no gravel composition adequate for digging/ground gleaning, prominence of washes, and sparse tree composition all comprise LCTH habitat.

- Concentrate training and development activities away from areas with current or historic records of Le Conte's thrashers. In addition, evaluate potential impacts to the local viability of thrashers, including habitat loss and fragmentation, when developing new training areas. This approach should reduce disturbance to important areas for LCTH and other species while reducing overall fragmentation of wildlife habitat. This study has provided more detailed locations of LCTH habitat within the BMGR and YPG and highlights important components of LCTH habitat that can be extrapolated to other areas. Thus, areas potentially suitable to LCTH occurrence can be more easily predicted across this species distribution and particularly where potential military training-related impacts are planned. This study also developed a LCTH Prediction of Occurrence Model that can be combined with geospatial data of military training activities, bombing ranges and areas slated for development (e.g., solar and wind arrays) to most effectively predict the potential impacts that these actions may have on LCTH.

- Create or maintain OHV closure to Le Conte's thrasher breeding areas. The borderlands region of the U.S. experiences a multitude of OHV disturbance from illegal activity and border patrols. LCTH surveyors noted that OHV footprints were ubiquitous throughout the study area and will continue to be difficult to police. Most survey locations contained evidence of OHV footprints to some degree. While LCTH persisted in many of these areas, the borderlands region receives regular traffic from OHVs and reducing this traffic falls under the auspices of the Department of Homeland Security. Determining the impacts of OHV use on LCTH occurrence is beyond the scope of this project and would be difficult and costly to achieve. We will attempt to include OHV footprints as a covariate during year 2 analyses.

The following research priorities would address knowledge gaps with respect to Le Conte's thrasher ecology and would improve our ability to proactively manage its habitat:

- Evaluate disturbance threshold of OHV to Le Conte's thrasher populations in the US and Mexico. OHV footprints are widespread throughout the borderlands region and it is difficult to correlate the impacts of OHV traffic on LCTH.

- Compare the habitat that LCTH are using versus what is available to them. This can be accomplished by measuring habitat variables at plots within Le Conte's territories in conjunction with measuring habitat variables at random plots.

- Other potential disturbances to LCTH are expected to increase including urban and agricultural development, wind and solar power. In the face of these potential threats, it is important to investigate the thresholds to which LCTH respond negatively to these disturbances. The refined LCTH PO Model (after year 2) will be a powerful tool for land managers to predict potential areas containing LCTH are most sensitive to disturbance. Describing actual threshold values that LCTH respond to in the context of development would require extensive tracking efforts (i.e., radio-telemetry) in areas outside of DoD responsibility.

- Initiate or continue monitoring the expansion of invasive plant species and their impact on Le Conte's thrasher populations in the US and Mexico.
- Develop and implement integrated management strategies to reduce wildfire fuel loads and further spread of invasive species. Evaluate effects of invasive species management on LCTH populations in US and Mexico.

REFERENCES

Bailey, L. L., T. R. Simons, and K. H. Pollock. 2004. Estimating site occupancy and species detection probability parameters for terrestrial salamanders. Ecological Applications 14:692-702.

Barry M. Goldwater Range (BMGR). 2007a. Integrated Natural Resources Management Plan (INRMP) (2007 – 2011), Barry M. Goldwater Range. Prepared by U.S. Department of the Air Force, Luke Air Force Base and U.S. Department of the Navy, Marine Corps Air Station Yuma. March 2007.

Barry M. Goldwater Range (BMGR). 2007b. Inventory and Management Plan, Barry M. Goldwater Range-East. Science Applications International Corp (SAIC), Tucson, AZ. ACES Project No. NURD71937. August 2007.

Blackman, S. T., S. F. Lowery and J. E. Diamond. 2010. Le Conte's Thrasher broadcast survey and habitat measurement, Barry M. Goldwater Range – East. Research Branch, Arizona Game and Fish Department.

Brown, D. E. 1994. Biotic communities: Southwestern United States and Northwestern Mexico. University of Utah Press. Salt Lake City, Utah.

Buckland S. T., D. R. Anderson, K. P. Burnham and J. L. Laake. 2001. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. 446 pp.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag. New York, New York.

CalPIF (California Partners in Flight). 2006. Version 1.0. The Desert Bird Conservation Plan: a Strategy for Protecting and Managing Desert Habitats and Associated Birds in the Mojave and Colorado Deserts. California Partners in Flight. Available: http://www.prbo.org/calpif /plans.html

Coachella Multi-species Habitat Conservation Plan (CMHCP). 2007. Available: http://www.cvmshcp.org.

Collier, B. A., M. L. Morrison, S. L. Farrell, A. J. Campomizzi, J. A. Butcher, K. B. Hays, D. I. MacKenzie and R. N. Wilkins. 2010. Monitoring golden-cheeked warblers on private lands in Texas. Journal of Wildlife Management 74(1): 140-147.

Corman, T. E. and Wise-Gervais, C. 2005. Arizona Breeding Bird Atlas. University of New Mexico Press, Albuquerque, NM.

Hansen, C. P., J. J. Millspaugh and M. A. Rumble. 2011. Occupancy modeling of ruffed grouse in the Black Hills National Forest. Journal of Wildlife Management 75(1): 71-77.

Henneman, C. and D. E. Andersen. 2009. Occupancy models of nesting-season habitat associations of red-shouldered hawks in central Minnesota. Journal of Wildlife Management 73(8): 1316-1324.

Hines, J. E. 2010. Program PRESENCE. U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland.

Kroll, A. J., S. D. Duke, D. E. Runde, E B. Arnett and K. A. Austin. 2007. Modeling habitat occupancy of orange-crowned warblers in managed forests of Oregon and Washington, USA. Journal of Wildlife Management 71(4): 1089-1097.

MacKenzie, D. I, J. D. Nichols, G. B. Lachman, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 82:2248-2255.

MacKenzie, D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. D. Franklin. 2003. Estimating site occupancy, colonization and local extinction probabilities when a species is not detected with certainty. Ecology 84:2200-2207.

MacKenzie, D. I., and L. L. Bailey. 2004. Assessing the fit of site occupancy models. Journal of Agricultural, Biological, and Environmental Statistics 9:300–318.

MacKenzie, D. I., and J. D. Nichols. 2004. Occupancy as a surrogate for abundance estimation. Animal Biodiversity and Conservation 27:461-467.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42:1105-1114.

MacKenzie, D. I. 2006. Modeling the probability of resource use: the effect of, and dealing with, detecting a species imperfectly. Journal of Wildlife Management 70:367-374.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, San Diego, California, USA.

Latta, M. J., C. J. Beardmore and T. E. Corman. 1999. Arizona Partners in Flight Bird Conservation Plan. Version 1.0. Nongame and Endangered Wildlife Program Technical Report 142. Arizona Game and Fish Department, Phoenix, Arizona.

Purcell, K. L., S. R. Mori and M. K. Chase. 2005. Design considerations for examining trends in avian abundance using point counts: examples from oak woodlands. Condor 107: 305–320.

Sheppard, J. M. 1970. A study of the Le Conte's Thrasher (*Toxostoma lecontei*). California Birds 1: 85-94.

Sheppard, J. M. 1996. Le Conte's Thrasher (*Toxostoma lecontei*). *In* Birds of North America 230 (A. Poole and F. Gills, Eds.). Philadelphia: Academy of Natural Sciences; Washington, DC: American Ornithologists' Union.

Tyre, A. J., B. Tenhumberg, S. A. Field, D. Niejalke, K. Parris, and H. P. Possingham. 2003. Improving precision and reducing bias in biological surveys by estimating false negative error rates in presence-absence data. Ecological Applications 13:1790-1801.

Villarreal, M.L., C. van Riper III, R.E. Lovich, R.L. Palmer, T.Nauman, S.E. Studd, S. Drake, A.S. Rosenberg, J. Malusa, and R.L. Pearce. 2011. An Inventory and Monitoring Plan for a Sonoran Desert Ecosystem: Barry M. Goldwater Range-West. U.S. Geological Survey Open-File Report 2011-1232.

Appendix 1. Randomly generated centers of Le Conte's thrasher survey plots

Plot ID	Range	LCTH Detection Locations	Easting (NAD 83)	Northing (NAD 83)
1	MCAS	12	231649	3615117
2	MCAS	8	774657	3607203
3	BMGRE	3	291232	3623229
5	MCAS	8	225385	3609340
6	BMGRE	12	272547	3620943
7	MCAS	1	777233	3599482
8	MCAS	4	735842	3607476
9	BMGRE	4	261144	3607159
10	YPG	0	753796	3667076
11	MCAS	4	249740	3604883
12	MCAS	1	772003	3579622
13	MCAS	4	241355	3609949
14	YPG	6	245033	3657724
15	YPG	0	744247	3655608
16	MCAS	1	250544	3595417
17	BMGRE	5	271492	3593667
18	MCAS	0	781063	3596174
19	BMGRE	3	249249	3622850
20	YPG	1	248916	3650748
21	BMGRE	6	256996	3619594
22	YPG	0	247397	3676847
23	MCAS	0	775543	3588063
24	BMGRE	0	293373	3631604
25	MCAS	1	781627	3591141
26	MCAS	5	771174	3600639
28	BMGRE	5	274502	3598025
29	BMGRE	0	252945	3616304
30	MCAS	1	236413	3593932
31	MCAS	0	767069	3584002
32	YPG	0	757467	3654720
33	MCAS	2	762474	3607583
34	BMGRE	1	333898	3609304
35	MCAS	7	774395	3593091
36	MCAS	5	230508	3601506
37	BMGRE	8	268101	3614367
38	BMGRE	0	249970	3619363
40	BMGRE	6	266659	3598273
22-2	YPG	0	250663	3681422
41	BMGRE	0	328729	3603609
43	YPG	5	247912	3653930